

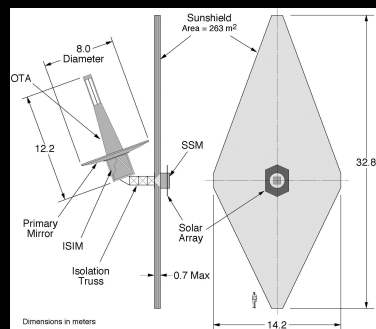


NEXT GENERATION NGST SPACE TELESCOPE

Introduction

The passive thermal design and analyses of NASA's Next Generation Space Telescope (NGST) Yardstick Integrated Science Instrument Module (ISIM) is described. The NGST mission concept of a large aperture optical telescope passively cooled to less than 40 K and instrument detectors passively cooled to below 30 K is unique from any other mission flown to date. Taking advantage of the low temperature sink provided by the observatory's large sunshield, the ISIM utilizes a three-stage multi-radiator configuration to passively cool the near infrared (NIR) detectors. Two radiators dissipate mechanism power and intercept parasitics before they reach the third primary radiator that radiates the detector's power dissipation. Warm and high dissipating electronics are thermally decoupled from the ISIM and have dedicated radiators. The primary ISIM structure is conductively isolated from the optical telescope assembly (OTA) and warm spacecraft bus. Passive cooling provides a robust, long-life, low-mass, and low-cost approach compared to the use of a stored-cryogen or mechanical cooler configuration for the 30 K operational range. If NGST's sensitivity is extended to 12 microns, a mechanical cooler is baselined to cool the mid-infrared (MIR) detectors to approximately 6 K. The presented thermal models and analyses require a high level of detail and precision to accurately predict the thermal loads on the radiators and mechanical cooler. Passive cooling analyses at these low temperatures is extremely sensitive to modeling errors. An extensive effort has been made to capture in the thermal models all of the parasitic and dissipation heat loads that may render passive cooling unfeasible. Illustrated results indicate that the current yardstick ISIM configuration is compatible with passive cooling and has adequate cryogenic thermal design margin. Results also illustrate the extreme importance of the NGST sunshield's thermal performance to successful ISIM passive cooling. This poster illustrates ISIM thermal results to date. ISIM thermal models are continually being updated to a greater fidelity as the mechanical design matures.

Configuration



NASA Yardstick NGST configuration illustrates the large size of the sunshield. The relatively warm spacecraft support module (SSM) and solar array are thermally separated from the cold OTA and ISIM by the sunshield and a low conductivity isolation truss. The sunshield configuration allows large sky visibility while maintaining complete shadow on the OTA enabling passive cooling of the mirrors and instrument.

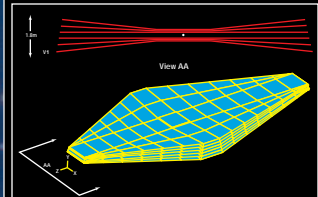
Thermal Design and Analysis of NASA's Next Generation Space Telescope (NGST) Yardstick Integrated Science Instrument Module (ISIM)

Keith Parrish, Diane Stanley, Jon Lawrence, Matthew Jurotich, NGST ISIM Team
NASA Goddard Space Flight Center, Greenbelt MD

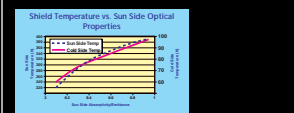
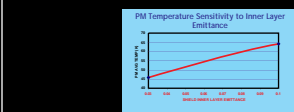
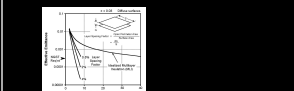
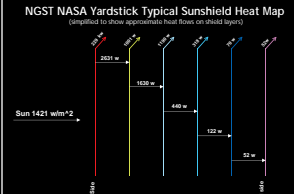
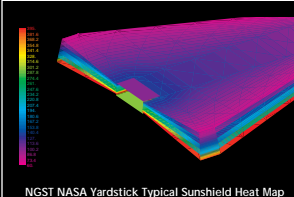
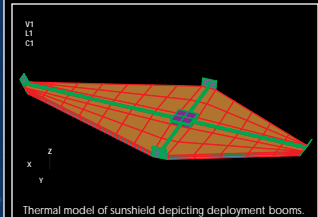
300 K to 30 K Passively

Sunshield Performance

A high performance/highly attenuating sunshield is the key element to ISIM passive thermal control.



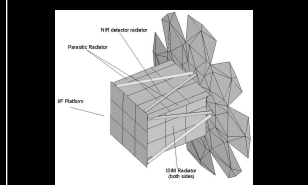
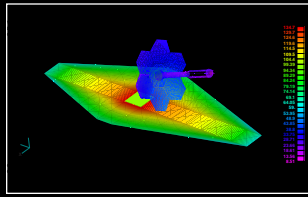
NGST Yardstick sunshield, circa 11/98. The sunshield not only shadows the OTA and ISIM but also highly attenuates and rejects any heat flowing through the shield before it reaches the ISIM. The NGST Yardstick sunshield consists of 6 separated Kapton layers. Except for the sun-facing layer side, low emittance/highly specular vapor deposited aluminum coats all layers. This coating minimizes radiative heat transfer between the layers. The Yardstick shield is flared or angled about the long axis providing large layer separation around the edges. Four booms deploy from the central storage container pulling out the six membrane layers.



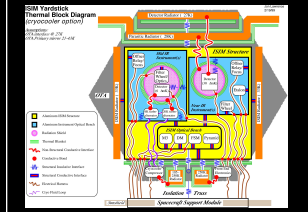
An example of some of the parameters affecting the shield's performance: VDA contamination, layer spacing and sun side thermo-physical optical properties.

ISIM Thermal Control Concept

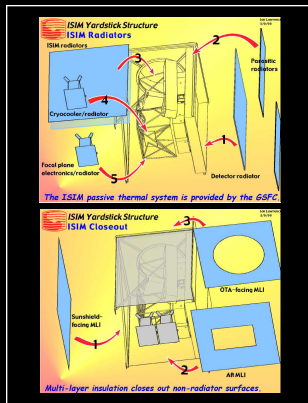
A cold OTA and sunshield make a passive control approach for the mid-IR detectors feasible.



Passive cooling of the ISIM's NIR detector to 30 K is achieved using a four stage radiator system with the first being the sunshield. The two large ISIM radiators, stage two, reject optical bench mechanism dissipation as well as intercept sun shield heat loads before reaching stage three, the parasitic radiator. The parasitic radiator thermally separates the relatively warm optical bench and camera optics (~35 - 40 K) and intercepts and rejects heat loads before reaching the final and coldest stage, the detector radiator. The large detector radiator, ~8m², is given maximum view to space and is sized to radiate the NIR detector power as well as residual parasitics.



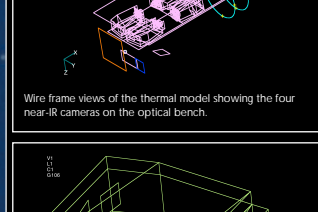
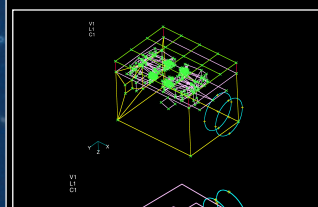
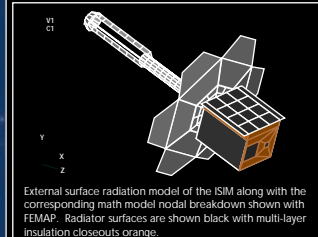
This mechanical block diagram illustrates the isolative and conductive links within the ISIM as well as to the spacecraft and OTA. Active cooling, via a mechanical Turbo-Brayton cooler or a stored cryogen dewar provides cooling to the MIR detectors to approximately 6 K. A low conductivity gamma-aluminum interface is baselined to provide conductive isolation from the OTA. The detectors are mounted within thermally isolating enclosures, which are coupled via copper straps to the parasitic radiator. Block Diagram not to scale.



Radiator installation sequence. Once the individual ISIM instruments are in place on the optical bench the ISIM thermal control system radiators are installed. The mid-IR detector cryocooler compressor and detector pre-amp electronics are given dedicated radiators. These radiators are sized to keep their temperature at approximately 200 K. Given the large temperature difference between these components and the rest of the ISIM, thermal isolation is critical. Gamma-alumina composite is the baselined structural support material.

ISIM Thermal Modeling

Concept level thermal models of the ISIM have been created as part of the overall NGST yardstick thermal models. As part of the NGST yardstick design effort, the NGST thermal systems modeling team has been testing the latest in concurrent thermal engineering tools while also using the more traditional SINDA and TRASYS thermal analyzers. Thermal DesktopTM, by Cullimore and Ring, is one of the newer concurrent engineering thermal analysis programs that has been used on a trial basis on NGST. Also used is TCON, by F.A. Costello Inc. along with its pre and post processor, FEMAP by Enterprise Software.



Thermal Modeling Assumptions - Power Dissipations

NIR Detectors (30K)	160 mW*
MIR Detectors	0 - bound at 6K heat load from model
NIR Cameras	26 mW
NIR Spectrometer	10 mW
TIR Camera/Spectrometer	12 mW
Fast Steering Mirror (FSM)	100 mW
Total Cold Component Dissipation	148 mW
Warm Components	
OP AMP Electronics	20 W(250K)
Cryo-Cooler Compressor	100 W @220K

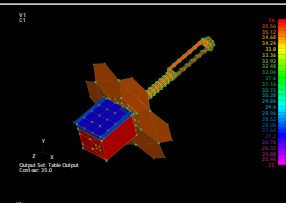
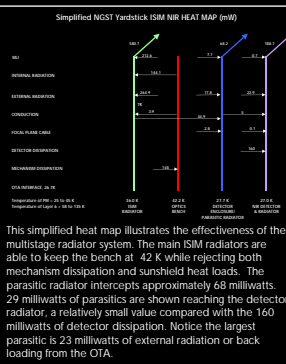
*based on 1 mW per megapixel and 100% margin

Other Key Modeling Assumptions

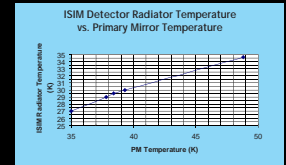
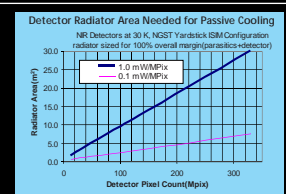
- Radiators are open faced honeycomb black painted. Honeycomb raises total hemispherical emittance from 0.3 to 0.7 at 30 K.
- All other surfaces assumed to be black painted or black anodized with an emittance of 0.3.
- ISIM radiators and optical bench aluminum.
- Structural thermal isolators assumed gamma aluminum, k=1.0 W/m-K at room temperatures. Drops with temperature.
- Cold side of sun shield 58 to 135 K.
- OTA primary mirror 25 to 45 K.
- Detectors copper strapped to radiator, k = 400 W/m-K at 30 K.
- Pre-amp to detector harness consists of 1600 manganin wires. Harness heat staged to ISIM and parasitic radiators.

Model Results

Thermal model results verify the validity of passive control. Results assume end-of-life sunshield performance.



This simplified heat map illustrates the effectiveness of the multistage radiator system. The main ISIM radiators are able to keep the bench at 42 K while rejecting both mechanism dissipation and sunshield heat loads. The parasitic radiator intercepts approximately 68 milliwatts. 29 milliwatts of parasitics are shown reaching the detector radiator, a relatively small value compared with the 160 milliwatts of detector dissipation. Notice the largest parasitic is 23 milliwatts of external radiation or back loading from the OTA.



Critical parameters impacting a potential passive design for the near-IR include detector size and sunshield performance.

The impact of detector size on the required radiator area is shown for two dissipation regimes. An order of magnitude reduction in dissipation does not result in a similar radiator size reduction due to the scaling influences of harness heat loads and conductive isolation mounts. While a 0.1 milliwatt per megapixel dissipation does significantly reduce the needed radiator area, the parasitics become a greater percentage of the radiator heat load leading to less certainty in the modeling results. Detector dissipations that 'swamp' or mask parasitic gains are desirable.

A small decrease in sunshield thermal performance can increase the primary mirror's average temperature. Shown is the impact of the primary mirror's temperature, an indicator of sunshield performance, on the ISIM detector radiator's temperature.